



5 The present invention is directed to structural support coverings for excavations, such as mines. More particularly, the present invention is directed to a polymeric membrane that is applied to the surfaces of an excavation to provide structural support.

When ground is excavated, structural supports are placed in the excavation to prevent the ground from collapsing into the excavated area. Mainly, the ground is supported by support rods that are placed along the excavation. These supports are typically steel reinforcing rods that are held in place by mechanical anchors and/or grouts. These supports provide the main protection against unplanned rock falls.

The excavation, however, exposes natural rock features, such as faults and joints, and can damage the ground by digging or blasting. In these excavations, such as mines, supports are needed to prevent rock falls. Structural beams provide the main support in the excavation to prevent major rock falls. However, minor rock falls can occur between the main supports. Even though they may be isolated or relatively small, they still pose a hazard to people working in the excavation.

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damage if it is installed close to the advancing face. Because it cannot be installed remotely, it is hazardous to install because of falling rock. It can be difficult to shotcrete over which causes relatively high rebound and lower substrate adhesion.

5 One possible alternative to a wire mesh would be to spray concrete (shotcrete) onto the rock face. However, this would be cost prohibitive to apply to all surfaces in an excavation. Also, shotcreting may not be able to be applied in all locations.

10 Sealants have been used in mines to prevent air leaks. Sealants, however, are not capable of providing structural support to a surface in an excavation. Generally, sealants are polymer in water dispersions. As a result, they cannot be applied to a surface at a thickness sufficient to provide support because of the water content. Also, the polymer in water dispersion prohibits quick setting of the
15 polymer on the surface, which in turn does not provide sufficient tensile strength.

What is needed in the art is a structural membrane that can be installed with minimal labor, can be installed remotely from the exposed rock face, offers weathering protection to the rock face, does not corrode, becomes effective with
20 minimal rock deformation, can be applied near the advancing face, is less prone to blast damage, and can be covered with shotcrete if deemed necessary.

It is desirable for the invention to provide a polymeric structural support membrane for providing support to exposed surfaces in an excavation.

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It is also desirable for the invention to provide a polymeric structural support membrane that has a tensile strength and thickness, and molecular weight that are sufficient to provide support to exposed surfaces in an excavation.

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SUMMARY OF THE INVENTION

The present invention provides a polymeric excavation structural support membrane comprising a polymer that is an initiator induced reaction product of a monomer; a fire retardant; and optionally at least one of a crosslinking agent, a second monomer, a smoke retardant, a rheology modifier, reaction rate modifier, a plasticizer, emulsifier, defoamer, filler, wet surface adhesion modifier, and coloring agent; wherein the monomer is selected from the group consisting of aryloxy alkyl acrylates, aryloxy alkyl methacrylates, and mixtures thereof; wherein the second monomer does not homopolymerize in the presence of the reaction rate modifier or the initiator; wherein the membrane has a tensile strength and thickness sufficient to provide support to exposed surfaces in an excavation.

A method of reinforcing exposed surfaces in an excavation with a polymeric structural support membrane comprising: applying to the exposed surface a mixture comprising a monomer; an initiator, a fire retardant; and optionally at least one of a crosslinking agent, a second monomer, a smoke retardant, a rheology modifier, reaction rate modifier, a plasticizer, emulsifier, defoamer, filler, wet surface adhesion modifier, and coloring agent; wherein the monomer is selected from the group consisting of aryloxy alkyl acrylates, aryloxy alkyl methacrylates, and mixtures thereof, wherein the second monomer does not homopolymerize in the presence of the reaction rate modifier or the initiator; and reacting the mixture; wherein the membrane has a tensile strength and thickness sufficient to provide support to the exposed surfaces in the excavation.

The present invention also provides a polymeric structural support membrane formed from the process comprising: applying to an exposed surface in an excavation a mixture comprising a monomer; an initiator, a fire retardant; and optionally at least one of a crosslinking agent, a second monomer, a smoke retardant, a rheology modifier, reaction rate modifier, a plasticizer, emulsifier, defoamer, filler, wet surface adhesion modifier, and coloring agent; wherein the monomer is selected from the group consisting of aryloxy alkyl acrylates, aryloxy

alkyl methacrylates, and mixtures thereof, wherein the second monomer does not homopolymerize in the presence of the reaction rate modifier or the initiator; and reacting the mixture; wherein the membrane has a tensile strength and a thickness sufficient to provide support to the exposed surfaces in the excavation.

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Preferably, the monomer is selected from the group consisting of monofunctional aryloxy alkyl acrylates, monofunctional aryloxy alkyl methacrylates, and mixtures thereof.

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DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to a polymeric structural support membrane for excavations. The membrane includes a polymer and a fire retardant.

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The polymer is a reaction product of a monomer selected from the group consisting of monofunctional monomers, di-functional monomers, tri-functional monomers, tetra-functional monomers, and mixtures thereof. By functional, it is meant that the monomer has at least one double bond reactive group that can react in a polymerization reaction through a double bond to form a polymer. Additionally,

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the monomer can include another functional group, which can be a double bond or another reactive group, that reacts to link one polymer chain to another polymer chain.

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The polymer is present in the membrane in an amount that provides the membrane with a tensile strength and thickness sufficient to provide support to exposed surfaces in an excavation. The polymer is generally present in an amount from about 30% to about 70% based on the weight of the membrane. In one embodiment, the polymer is present in the membrane from about 51% to about 70% based on the weight of the membrane.

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The monofunctional monomers used according to the present invention are monofunctional esters, particularly monofunctional aryloxy alkyl acrylates,

monofunctional aryloxy alkyl methacrylates, and mixtures thereof. The methacrylates are preferred because they produce less odor.

Examples of useful monofunctional aryloxy alkyl acrylates and monofunctional aryloxy alkyl methacrylates include, but are not limited to, 2-phenoxyethyl methacrylate, 2-phenoxy-propyl-methacrylate, and mixtures thereof. Other monofunctional monomers that can be reacted to form the membrane of the present invention include, but are not limited to, tri-propylene glycol diacrylate, tri-ethylene glycol dimethacrylate, and mixtures thereof.

The di-functional monomers can be any di-functional ester. Di-functional esters that can be used are di-functional aryloxy alkyl acrylates, di-functional aryloxy alkyl methacrylates, and mixtures thereof. Examples of useful di-functional monomers include, but are not limited to, tri-ethylene glycol dimethacrylate, neopentyl glycol diacrylate or methacrylate, and tri-propylene glycol diacrylate.

The tri-functional monomers can be any tri-functional ester. Tri-functional esters that can be used are tri-functional acrylates, tri-functional methacrylates, and mixtures thereof. Examples of useful tri-functional monomers include, but are not limited to, propoxylated trimethylolpropane triacrylate, ethoxylated trimethylpropane triacrylate, and propoxylated glyceryl triacrylate.

The tetra-functional monomers can be any tetra-functional esters. Tetra-functional esters that can be used are tetra-functional acrylates, tetra-functional methacrylates, and mixtures thereof. Examples of useful tri-functional monomers include, but are not limited to, di-trimethylolpropane tetra acrylate, and dipentaerythritol penta acrylate.

Preferably, the polymer is the reaction product of a monomer selected from the group consisting of monofunctional aryloxy alkyl acrylates, monofunctional aryloxy alkyl methacrylates, and mixtures thereof, and a crosslinking agent.

During the reaction process a selected monofunctional monomer forms polymers that crosslink by reacting with the crosslinking agent thereby providing structural support for the membrane. Suitable examples of the crosslinking agent include, but are not limited to, methylene bis acrylamide, polymethylmethacrylate, butadiene styrene acrylate, styrene butyl acrylate copolymer, 1,6-hexanediol dimethacrylate, ethoxylated bisphenol A dimethacrylate, polyethylene glycol dimethacrylate, and mixtures thereof. The crosslinking agent can be present up to about 30% based on the weight of the monomer.

10 A second monomer may be included in the reaction product that forms the membrane of the present invention. The second monomer preferably does not homopolymerize in the presence of the reaction rate modifier or the initiator. Suitable examples of the second monomer include, but are not limited to, diethylene glycol monoethyl ether dimethacrylate, diethylene glycol monobutyl ether
15 dimethacrylate, and mixtures thereof.

Because the membrane is being applied in an excavation, particularly in a mine, there is the potential for fire. In each jurisdiction, there are requirements that the membrane be self extinguishing. The test is performed by holding the
20 membrane to a flame for a fixed period of time. The membrane must then self extinguish itself within a set maximum time.

Provided in the membrane is a fire retardant. The fire retardant can be any material that provides self extinguishing properties to the membrane. Suitable
25 examples of the fire retardant include, but are not limited to, phosphates, such as triphenyl phosphate, polyammonium phosphate, monoammonium phosphate, or tri(2-chloroethyl) phosphate, exfoliated graphite (which can be acid treated natural graphite flakes), and mixtures thereof. The fire retardant is preferably present in the membrane from about 5 to about 40% based on the weight of the membrane.

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The fire retardant can be a liquid or a solid. Preferably the fire retardant is a solid. More preferably, the solid is micronized. By micronized it is meant that the

solid is ground to a micron size. Additionally, the fire retardant includes but is not limited to self extinguishing agents and flame retardants. A preferred fire retardant is polyammonium phosphate. Optionally, an aluminum oxide smoke retardant is used in combination with the polyammonium phosphate.

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As stated above, a smoke retardant can be provided in the membrane. A preferred smoke retardant is aluminum oxide (Al_2O_3). Preferably, the smoke retardant is present in the membrane from about 2% to about 15% based on the weight of the membrane.

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The gel and set time of the membrane can be controlled by adding at least an initiator. The initiator can be an oxidizing agent. Suitable oxidizing agents include, but are not limited to, peroxides, such as benzoyl peroxide, dibenzoyl peroxide, hydroperoxides, such as cumyl hydroperoxide, persulfates, such as ammonium persulfate, and mixtures thereof. The initiator is preferably added in an amount from about 1% to about 10% based on the weight of the monomer.

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In combination with the initiator, a reaction rate modifier, such as an accelerator, can be added. The reaction rate modifier can be a reducing agent. Suitable reducing agents include, but are not limited to, aniline containing compounds, amines, glycols, octoates, and mixtures thereof. Suitable examples of the reaction rate modifier include, but are not limited to, triethanolamine, N,N-dimethyl-p-toluidine, and tripropyl amines. The reaction rate modifier can be present in an amount up to about 10% based on the weight of the monomer.

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The materials to form the membrane can either be provided as a single composition, or the materials can be provided as a two or more component formulation. The two or more component system may be desired when an initiator and a reaction rate modifier are being provided for in the membrane. In this instance, the initiator would be supplied in one component, and the reaction rate modifier could be supplied in another component.

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The membrane can also include a rheology modifier to increase the viscosity of the membrane materials immediately after application to excavation surfaces. This may be desired to prevent the membrane from slumping before it cures when it is applied to a surface in an excavation. Suitable examples of the rheology modifier include fumed silica, hydroxyethyl cellulose, hydroxypropyl cellulose, fly ash (as defined in ASTM C618), mineral oils (such as light naphthenic), tetra alkyl ammonium hectorite clay, any other solids that are inert to the other materials in the membrane, and mixtures thereof. The rheology modifier can be present in an amount up to about 20 %based on the weight of the membrane.

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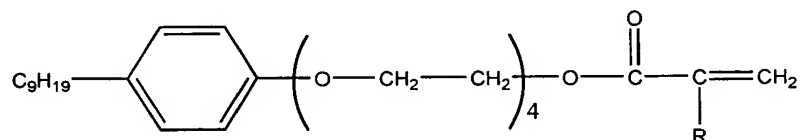
The membrane can also include an emulsifier. It may be desired to add an emulsifier to increase the adhesion of the membrane to a surface. The emulsifier can be any anionic surfactant or nonionic surfactant. Suitable examples of the emulsifier include, but are not limited to, ethoxylated nonyl phenol (preferably, the ethoxylated nonyl phenol contains from about 4 to about 10 ethylene oxide groups), lauryl sulfates and mixtures thereof. The emulsifier can be present in an amount up to about 5% based on the weight of the monomer.

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The membrane can also contain a plasticizer to make the membrane more flexible. The plasticizer can be any material that plasticizes the polymer in the membrane. In one embodiment of the invention, the plasticizer allows the polymer to be self plasticizing. In this instance, the monomer is reacted with the plasticizer that incorporates itself into the reaction product. The plasticizer can be present in an amount up to about 40% based on the weight of the monomer. Suitable examples of the plasticizer include, but are not limited to, lauryl methacrylates, stearyl methacrylates, and ethoxylated(4) nonyl phenol (meth)acrylate, as shown by the following formula:

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wherein R is H or CH₃.

The membrane can also include a filler. Suitable examples of the filler include, but are not limited to glass, such as crushed glass, metal such as iron particles, quartz, silica, barytes, limestone, sulfates, alumina, various clays, diatomaceous earth, wollastonite, mica, perlite, flint powder, kryolite, alumina trihydrate, talc, sand, pyrophyllite, granulated polyethylene, fibers such as polypropylene or steel, zinc oxide, titanium dioxide, and mixtures thereof. A preferred filler is titanium dioxide. The filler can be present in an amount up to about 40% based on the weight of the monomer.

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The membrane can also include a wet surface adhesion modifier. The wet surface adhesion modifier provides for increased adhesion to wet surfaces. The wet surface adhesion modifier can be any material that increases the adhesion of the membrane to a wet surface. Suitable examples of the wet surface adhesion modifier include, but are not limited to, metallic acrylate or methacrylate at up to about 10% of total monomer content, ammonium oleate, magnesium oleate, ammonium acrylate and metal borates. A preferred wet surface adhesion modifier is zinc borate. The wet surface adhesion modifier is preferably present in an amount up to about 3% based on the weight of the monomer.

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The membrane can also include a coloring agent, such as a pigment or a dye, to provide a desired color to the membrane. An example of a coloring agent is titanium dioxide, but other coloring agents are also useful. The coloring agent can be present in an amount up to about 3% based on the weight of the monomer.

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The membrane can also include a defoamer such as modified silicones or petroleum oil mixtures. A preferred defoamer is FOAMASTER™ S available from Cognis Corporation, Cincinnati, Ohio. The defoamer can be present in an amount up to about 3% based on the weight of the monomer.

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A preferred membrane is formed from a two component reaction mixture. The first component includes the monomer, the fire retardant, and the crosslinking

agent that react to become the polymeric membrane and any other additive for example a second monomer, a smoke retardant, a rheology modifier, reaction rate modifier, a plasticizer, emulsifier, defoamer, filler, wet surface adhesion modifier, and coloring agent. The second component includes the initiator and any other
5 additive. The two component mixture is preferred so that the monomer does not prematurely react with the initiator. To form the membrane, the two components are mixed and allowed to react.

When applied to a surface, the membrane should be at least about 1.5mm
10 thick. Preferably, the membrane is about 2mm to about 6mm thick.

One property of the membrane is elongation. Elongation is the percent increase in length of a membrane before it breaks (ASTM D638). It is desired to achieve elongation in the shortest amount of time. Preferably, the membrane has an
15 elongation greater than about 25% after 24 hours from being formed. More preferably, the membrane has an elongation greater than about 50% after 8 hours. Most preferably, the membrane has an elongation greater than about 75% after 2 hours. In some embodiments, however, the membrane has an elongation of about zero. In these instances, the membrane is substantially rigid.

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Another property of the membrane is tensile strength. Tensile strength is the maximum force that a membrane can withstand before breaking (ASTM D638). It is desired to achieve a high tensile strength. Preferably, the membrane has a tensile strength greater than about 1 MPa after 24 hours. More preferably, the membrane
25 has a tensile strength greater than about 1 MPa after 6 hours. Most preferably, the membrane has a tensile strength greater than about 1 MPa after 30 minutes or less.

The membrane also has an adhesion property. Adhesion is measured by the force needed to remove the membrane from a surface (ASTM D4142). It is desired
30 to achieve adhesion in the shortest amount of time. Preferably, the membrane has an adhesion strength greater than about 0.5 MPa after 24 hours. More preferably, the membrane has an adhesion strength greater than about 1 MPa after 8 hours.

Most preferably the membrane has an adhesion strength greater than about 0.5 MPa after 30 minutes or less.

It is preferred that the membrane have water resistance. Water resistance
5 can be determined by the following standards: ASTM D2247 (Standard Practice for Testing Water Resistance of Coatings in 100% Relative Humidity), ASTM D1735 (Standard Practice for Testing Water Resistance of Coatings Using Water Fog Apparatus), ASTM D4585 (Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation), or ASTM D870 (Standard Practice for
10 Testing Water Resistance of Coatings Using Water Immersion).

The preferred standard is ASTM D870. A sample of the membrane is immersed in room temperature water for a period of about 24 hours. The tensile strength of the membrane is then measured and compared to the tensile strength of
15 the membrane before immersion. Greater water resistance is indicated by having a lower loss in tensile strength. Acceptable water resistance is having a loss in tensile strength less than about 10%. Preferably, the loss in tensile strength is less than about 5%. It has been found that aryloxy alkyl acrylates and aryloxy alkyl methacrylates provide acceptable water resistance to the membrane of the present
20 invention.

The membrane is also capable of quick set. By quick set it is meant that the membrane achieves at least one of the tensile, elongation, and adhesive properties within the time referenced above.
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It is also preferred that the membrane have a useful service life greater than one year. By useful service life, it is meant that the membrane has less than about 10% loss of properties in one year.

30 Because the membrane may be applied underground in a mine, it is preferred that the membrane be non-toxic to human contact.

In another embodiment of the present invention there is provided a method of reinforcing exposed surfaces in an excavation with a polymeric structural support membrane. The method includes providing a mixture of a polymer that is an initiator induced reaction product of a monomer; a fire retardant; and optionally at least one of a crosslinking agent, a smoke retardant, a rheology modifier, reaction rate modifier, plasticizer, emulsifier, defoamer, filler, wet surface adhesion modifier, and coloring agent; wherein the monomer is selected from the group consisting of aryloxy alkyl acrylates, aryloxy alkyl methacrylates, and mixtures thereof; wherein the membrane has a tensile strength and a thickness sufficient to provide support to exposed surfaces in an excavation; and applying said mixture to an exposed surface in an excavation. This method provides for applying the above described polymeric structural support membrane on an exposed surface.

Sufficient membrane tensile strength and thickness to provide support for exposed surfaces in an excavation can be measured using the testing method illustrated in A. Spearing, Jeffrey Ohler & Emmanuel Attiogbe, The effective testing of thin support membranes (superskins) for use in underground mines, Australian Centre for Geomechanics, herein incorporated by reference. The test, referred to as MBT Membrane Displacement Test, is designed to provide load and displacement data on membrane performance to account for the combined effects of tensile strength, elongation and adhesion properties of spray-on membranes and provide performance data for evaluating such membranes. It is effective in comparing the relative performance of different membranes. The membrane is sprayed onto the surface of a concrete slab. An area of the applied membrane is then subjected to a load. Both short- and long-term (i.e., creep) tests can be performed with the test setup. For ease of developing a standard test that can be routinely used to assess the overall performance of spray-on membranes, pre-cast concrete slabs are used. These slabs are commercially available and are quite dense (relative to normal cast-in-place concrete) with a slightly textured finish on one surface. Typical values of absorption and volume of permeable pore space for the slabs, as determined in accordance with ASTM C 642, are 5% and 11%, respectively. Using the pre-cast slab, the performance of the membrane can be evaluated for the effects

of variations in membrane properties, as well as the effects of substrate moisture conditions.

- 5 The mixture can be applied by spraying, brushing, or rolling to provide the polymeric structural support membrane on an exposed surface. A preferred embodiment of the present invention is prepared from the following formulation. It is provided in the preferred two component formulation with the monomer and initiator being provided in separate parts to the formulation.

PART A	
2-phenoxyethyl methacrylate	Monomer
ethoxylated bisphenol A dimethacrylate	Cross-linking agent
N,N-Dimethyl-P-Toluidine	Reaction rate modifier
natural graphite flake	Flame retardant/fire retardant
fumed silica	Rheology modifier
mineral oil (light naphthenic)	Rheology modifier
titanium dioxide	Coloring agent, filler
zinc borate	Wet surface adhesion modifier
FOAMASTER S	Defoamer
PART B	
tri(2-chloroethyl)phosphate	Fire retardant
mineral oil (light naphthenic)	Rheology modifier
benzoyl peroxide	Initiator
fumed silica	Rheology modifier
zinc borate	Wet surface adhesion modifier
FOAMASTER S	Defoamer

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In another preferred embodiment, the present invention is prepared from the following formulation. Again, this embodiment is provided in the preferred two component formulation with the monomer and initiator being provided in separate parts to the formulation.

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PART A	
2-phenoxyethyl methacrylate	Monomer
ethoxylated bisphenol A dimethacrylate or trimethylolpropane trimethacrylate	Cross-linking agent
N,N-Dimethyl-P-Toluidine	Reaction rate modifier
ethoxylated(4) nonyl phenol (meth)acrylate	Plasticizer
polyammonium phosphate/ Al_2O_3	Fire retardant/smoke retardant
fumed silica	Rheology modifier
mineral oil (light naphthenic)	Rheology modifier
titanium dioxide	Coloring agent, filler
zinc borate	Wet surface adhesion modifier
FOAMASTER S	Defoamer
PART B	
polyammonium phosphate/ Al_2O_3	Fire retardant/smoke retardant
benzoyl peroxide	Initiator
mineral oil (light naphthenic)	Rheology modifier
fumed silica	Rheology modifier
zinc borate	Wet surface adhesion modifier
FOAMASTER S	Defoamer

In another preferred embodiment, the present invention has the following three component formulation. The three component formulation comprises the monomer, initiator and reaction rate modifier which are provided in separate parts to the formulation. This embodiment can additionally contain filler, rheology modifiers, a second monomer, and coloring agents.

PART A	
2-phenoxyethyl methacrylate	Monomer
trimethylolpropane trimethacrylate	Cross-linking agent
polyammonium phosphate/ Al_2O_3	Fire retardant/smoke retardant
fumed silica	Rheology modifier
Aluminium Oxide	Smoke retardant
FOAMASTER S	Defoamer

PART B	
diethylene glycol monoethylether methacrylate	Non-homopolymerizable monomer
benzoyl peroxide	Initiator
fumed silica	Rheology modifier
Aluminium Oxide	Smoke retardant
FOAMASTER S	Defoamer
PART C	
diethylene glycol monoethylether methacrylate	Non-homopolymerizable monomer
N,N, Dimethyl P Toluidine	Reaction rate modifier
FOAMASTER S	Defoamer

In another preferred embodiment the formulation comprises four components. This embodiment is provided in a four component formulation combined in two units of monomer, initiator and reaction rate modifier, as discussed below.

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PART A	
2-phenoxyethyl methacrylate	Monomer
trimethylolpropane trimethacrylate	Cross-linking agent
polyammonium phosphate/ Al_2O_3	Fire retardant/smoke retardant
fumed silica	Rheology modifier
Aluminium Oxide	Smoke retardant
FOAMASTER S	Defoamer
titanium dioxide	Coloring Agent, filler
PART B	
diethylene glycol monoethylether methacrylate	Second monomer
N,N, Dimethyl P Toluidine	Reaction rate modifier
fumed silica	Rheology modifier
titanium dioxide	Coloring Agent, filler
PART C	
2-phenoxyethyl methacrylate	Monomer
fumed silica	Rheology modifier
titanium dioxide	Coloring Agent, filler

PART D	
benzoyl peroxide	Initiator
diethylene glycol monoethylether methacrylate	Second monomer
fumed silica	Rheology modifier
titanium dioxide	Coloring Agent, filler
polyammonium phosphate/ Al_2O_3	Fire retardant/smoke retardant

Preferably, this embodiment can be reacted to form the membrane of the present invention by supplying the four components through a pump that delivers the materials to a spraying apparatus to spray the formulation onto a surface.

5 Generally, the pump is designed to pump two components simultaneously. Components one (PART A) and two (PART B) are supplied to one pumping chamber of the pump, and components three (PART C) and four (PART D) are supplied to a second pumping chamber of the pump. The volumes of the components are sized such that the membrane is formed with the desired composition. In a preferred embodiment, a pump is used that delivers two combinations of components (units) in the volume ratio of about 3 to 1. In this embodiment, components one and two are sized to provide a unit of 3/4 of the total volume of the material delivered that forms the membrane, and components three and four are sized to provide a unit of 1/4 of the total volume.

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EXAMPLE

An example of the present inventive polymeric structural support membrane was tested for tensile strength ASTM D638 and elongation ASTM D638 both in the presence of water and without water. The example of the invention comprises two components (3 parts of Part A to 1 part of Part B (by weight)) which were added together to react and form the support membrane. In part A three monomers were used in order to maximize the flexibility (elongation), strength (tensile strength) and water sensitivity of the structural support membrane. 2 - phenoxyethyl methacrylate imparts decreased water sensitivity but lacks strength and flexibility whereas, the remaining two monomers hydroxy propyl methacrylate and isobornyl methacrylate give the membrane strength and flexibility.

Table 1

Part A		
		% of total mixture weight
Monomer (mixture)	2-phenoxyethyl methacrylate	37.59
	hydroxy propyl methacrylate	22.55
	isobornyl methacrylate	15.04
Cross-linking agent	ethoxylated bisphenol A dimethacrylate	3.78
Reaction rate modifier	N,N-dimethyl-p-toluidine	0.53
Flame retardant/ self-extinguishing agent	Grafguard 220-80B	5.66
Rheology modifier	Bentone 38	11.71
	Aerosil R 202	1.89
Coloring agent, filler	Titanium dioxide	0.90
Defoamer	Foamaster S	0.35
Part B		
		% of total mixture weight
Self-extinguishing agent	tri(2-chloroethyl)phosphate	74.63
Initiator	benzoyl peroxide	14.93
Rheology modifier	Bentone 38	7.46
	Aerosil R 202	2.98

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Table 2

Measured Membrane Property			
Air Cure			
	@1 hr.	@ 1 day	@ 7 days
Tensile strength (MPa)	1.3	1.5	1.3
Elongation (%)	140	129	113
Moist Cure			
		@ 1 day	@ 7 days
Tensile strength (MPa)		1.5	1.1
Elongation (%)		120	136

The example was tested for elongation (ASTM D638) – the percent increase
 10 in length of a membrane before it breaks, and tensile strength (ASTM D638) – the
 maximum force that a membrane can withstand before breaking expressed in
 megapascals. As illustrated by the results in Table 2, the polymeric structural
 support membrane achieves the desired tensile strength (greater than 1 MPa after 24
 hours) and elongation (greater than about 25% after 24 hours). Therefore, the
 15 membrane will display the desired strength and flexibility for an underground
 structural support. Additionally, the test results demonstrate that the polymeric

structural support membrane shows little or no strength loss when exposed to water (moisture sensitivity).

5 Although the invention has been described in detail through the above detailed description and the preceding formulations and example, these examples are for the purpose of illustration only and it is understood that variations and modifications can be made by one skilled in the art without departing from the spirit and the scope of the invention.